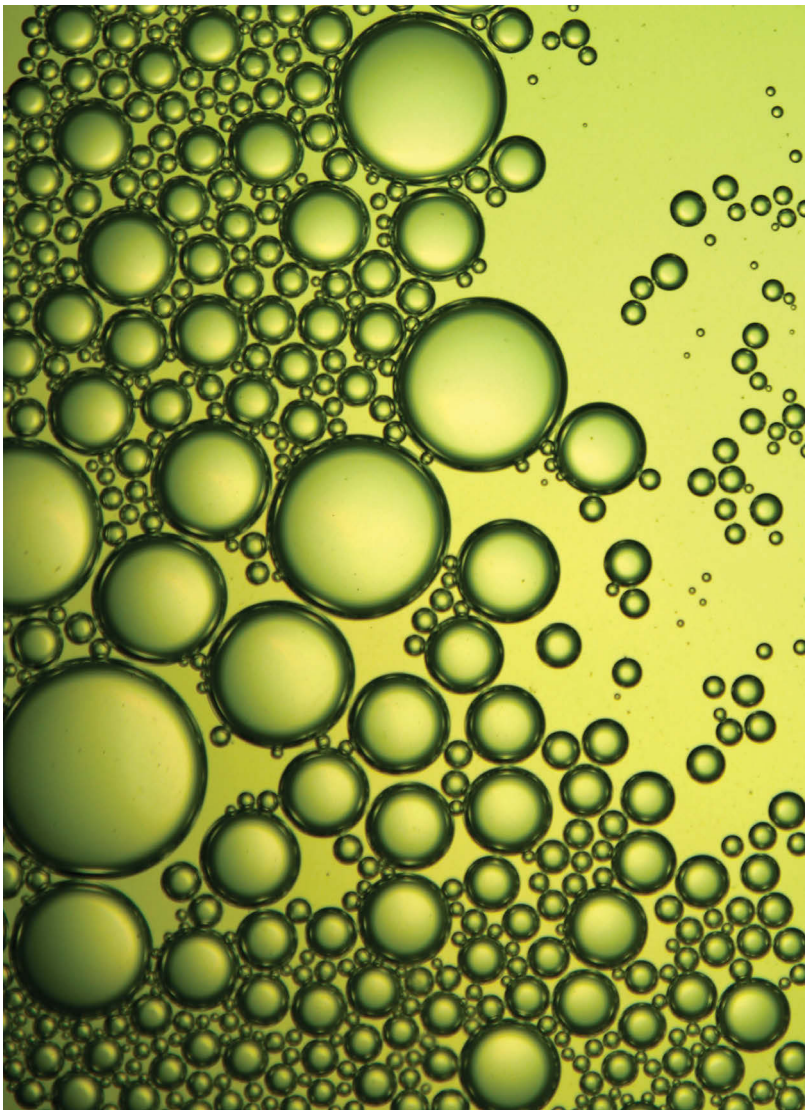
Enhancing Biofuel Production from a Marine Microalgae- Constraints of cultivation scale-up



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Certificate of Original Authorship

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any quotations, ideas and help that I have received in my research work and during the preparation of the thesis itself have been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signed: _____

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Preface

This thesis has been prepared in publication format, whereby each chapter represents a manuscript ready for submission to a peer-reviewed journal. As of yet, no individual chapter has been accepted for publication in a peer-reviewed journal.

In association with my PhD, I have been co-author on two publications that are relevant to the thesis, but does not contribute to it. The work presented in Tamburic et al .2014 lead up to the work presented in **Chapter 2**. The concepts and methods underlying Baker et al. 2016 provide the foundations for the work presented in **Chapter 3**.

Tamburic, B., Guruprasad, S., **Radford, D.T.**, Szabó, M., Lilley, R.M., Larkum, A.W.D., Franklin, J.B., Kramer, D.M., Blackburn, S.I., Raven, J. A, Schliep, M. & Ralph, P.J. 2014. The Effect of Diel Temperature and Light Cycles on the Growth of *Nannochloropsis oculata* in a Photobioreactor Matrix. *PloS one*, *9*, *1*, p. e86047.

Baker, K.G., Robinson, C.M., **Radford, D.T**., McInnes, A.S., Evenhuis, C. and Doblin, M.A., 2016. Thermal performance curves of functional traits aid understanding of thermally induced changes in diatom-mediated biogeochemical fluxes. *Frontiers in Marine Science*, *3*, p.44.

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Abstract

The current global dependence on liquid fossil fuels is not sustainable and as a result, the development of alternative renewable liquid fuel sources is paramount for future economic, environmental and social security. The production of liquid biofuels from marine microalgae offers a solution, due to its carbon-neutral capacity (mitigating increasing anthropogenic carbon dioxide) and its minimal impact on existing food and freshwater resources. In order to satisfy global demand for liquid fuel, the cultivation of microalgae is required at commodity scales; however, major challenges exist in order to ensure production is economically and sustainably viable. The aim of this thesis was to assess some of the key environmental constraints of industrial scale cultivation of microalgae, including: exposure to complex abiotic conditions; effective delivery of nutrient inputs and harnessing algal physiology to improve the viability of microalgae cultivation for biofuel production. To accomplish these aims, the application of quantitative physiological techniques in conjunction with a novel photobioreactor platform (ePBR; Phenometrics®) enabled us to assess the biological response of a biofuel candidate algae strain, *Nannochloropsis oculata*, following exposure to different environmental conditions and nutrient input scenarios.

My thesis revealed complex responses of *N. oculata* to a variety of environmental conditions. The response to changing light and temperature environments was found to be influenced by the growth stage of the algal culture, whilst comparisons between productivity under laboratory versus simulated outdoor conditions showed sinusoidal light dominates the diel effect of temperature oscillations in determining final yields. Exposure of *N. oculata* to a range of temperature conditions emphasised the wide thermal envelope of growth and therefore, the suitability of this algae strain for use inbiofuel production. Moreover, physiological algal traits were found to respond to the magnitude and duration of exposure to sub-optimal temperatures. Acclimation to nutrient conditions provide evidence of how natural cellular mechanisms can be harnessed to reduce the initial nutrient input, and how optimisation of nutrient delivery can be used to produce alternative products of interest. In my thesis, the suitability of the ePBR platform in conjunction with physiological methods such as *in vivo* chlorophyll fluorescence was used to examine the challenges of industrial cultivation. Several important avenues for future biofuel research are highlighted including: the better understanding of recovery of cultures from different magnitudes of environmental stress and harnessing the inherent acclimation process of microalgae to reduce system inputs will help to drive the future sustainability of the algal biofuels industry.